

suited to a wide variety of uses, both fresh and processed. Most apples are grown for the fresh market. A few varieties are grown primarily for processing and some dual-purpose varieties are well suited for both.

The apple processing industry is a natural outgrowth of the specialization and concentration of apple growing areas. The transition from farm industry to a large-scale industry is well advanced in the United States, Canada, and many European countries.

Prior to 1900, apple growing and processing in the United States was largely a farm-and-home operation. The commercial manufacture of canned slices and dried slices began about 1900. This was followed by canned applesauce in 1925, canned apple juice in 1935, and frozen slices around 1938. By 1935 about 18% of the U.S. apple crop was processed. This percentage increased to 43% by the late 1960's.

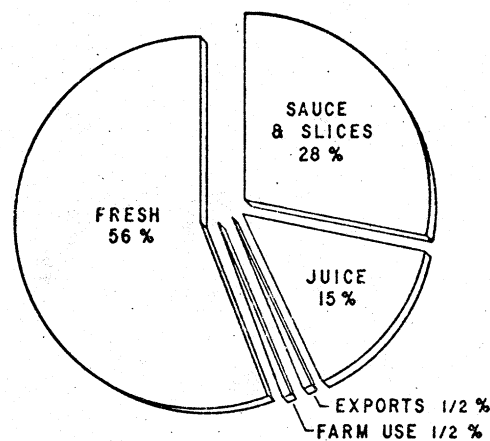


FIG. A-6. UTILIZATION OF APPLE CROP IN THE UNITED STATES, 1965-1969

Total consumption of apples and apple products in the United States is about 29 lb per capita per year. Apple consumption in Central Europe is much higher: France 135, Switzerland 112, Austria 98, and West Germany 83 lb per capita. In Europe, special cider varieties are grown exclusively for the manufacture of fresh or fermented cider. In the United States, apples are grown primarily for fresh market. The culls from the fresh market and dual-purpose varieties plus a few varieties grown for processing, constitute the raw materials for a steadily expanding processing industry.

The major apple varieties grown in the United States may be grouped into three categories according to use: (1) fresh market, 39% of total

APPLE PROCESSING

Apples are the most versatile of all deciduous fruits. They possess a unique combination of crisp texture and pleasing flavor that makes them well

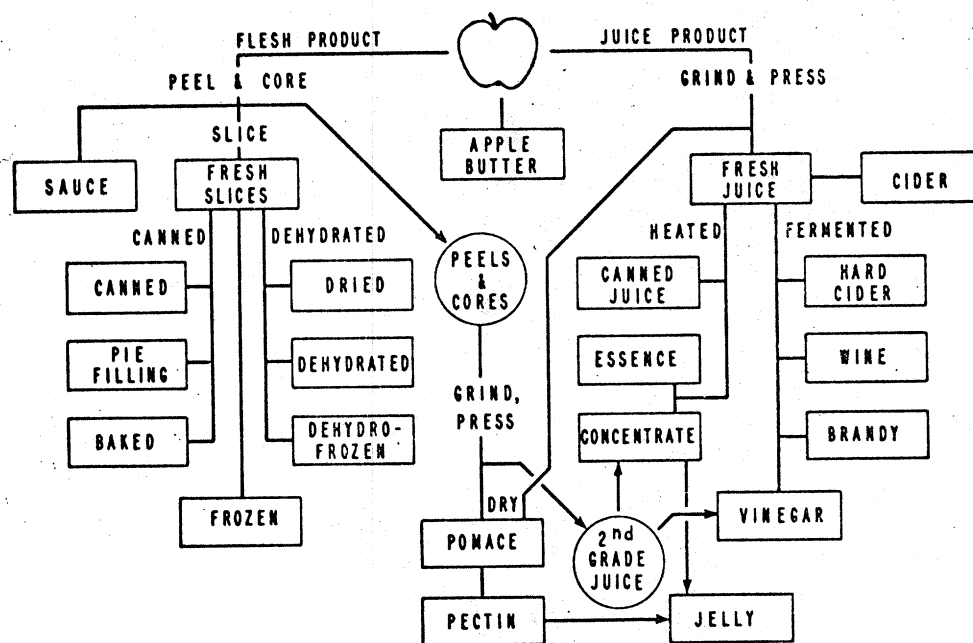


FIG. A-7. PRINCIPAL PROCESSED PRODUCTS FROM APPLES

crop: Red Delicious, Jonathan, Winesap, and Grimes Golden; (2) dual-purpose, 47%: McIntosh, Golden Delicious, Rome, Stayman, Yellow Newtown, Cortland, and Wealthy; (3) processing, 14%: York Imperial, Rhode Island Greening, Northern Spy, Baldwin, and Gravenstein.

Apple products may be divided into two broad groups: flesh products which include sauce, various slice products, and baked apples; and juice products.

Flesh products are usually peeled and cored. The peels and cores may be utilized in the manufacture of various by-products. Juice products are prepared by first grinding and pressing the fruit. The press cake may be dried for use as cattle feed or for pectin manufacture.

The sale of apple products is regulated by the general provisions of the Food and Drug laws. In addition, the USDA has established grades for apples for fresh market, for apples for processing, and for various apple products as an aid in establishing quality.

Sauce and Slice Products

Apples to be used in the manufacture of sauce or slices must have good texture, a minimum of defects requiring trimming, and sufficient size to be peeled economically. The following relation of size to yield of slices shows the importance of size in the processing operation:

Size (In.)	Yield of Slices (%)
3	78
2.75	73
2.50	66
2.25	53

Size also affects the volume of fruit that can be peeled per machine per hour, and, in turn, the output of a factory and the labor cost. Apples smaller than 2.25 in. diameter are not economical to peel but may be used in juice products or apple butter. In these latter products the entire apple is used, hence size is not a factor.

The importance of size is also reflected in prices paid to growers. The following prices were paid for processing grade apples in New York State in the late 1960's: 2.75 in. diameter and up, \$3.00 per cwt; 2.50-2.75 in., \$2.50; 2.25-2.50 in., \$1.50; and culls \$0.75 per cwt.

Applesauce

Applesauce is by far the most important apple product in the United States. It surpasses apple juice by 2 to 1 and outranks canned slices in volume by nearly 9 to 1. Over 27 million cases of sauce, including some 733,000 cases of baby food applesauce, were packed in the United States in 1969. The sauce pack has nearly doubled in

volume in the last 10 yr. Applesauce is manufactured chiefly for the retail trade and is used as a meat accompaniment, as a dessert, or as a cake ingredient. A moderate volume of applesauce is packed in Canada, about equal to canned slices. Only small quantities of sauce are packed in Europe.

Nearly all applesauce is made from apples that are peeled and cored mechanically. Each machine requires an operator to feed the apples, one at a time, and position them with the stem-calyx axis in the proper direction. The usual peeling machine has a capacity of 50-75 apples per minute (2-4 tons per day). Peels and cores account for roughly 30% of the apple. Because of the loss of product and the labor involved in mechanical peeling, several other methods have been proposed. In recent years, automatic knife peelers and corers have been built which do not require hand-positioning of the fruit. Also, a system of lye-peeling has been developed which reduced peel losses to less than 10%. A preliminary dewaxing with hot isopropyl alcohol vapor reduces the time and temperature required for lye-peeling.

The peeled and cored apples are trimmed by hand to remove bits of skin, bruises, and other defects. The fruit is then chopped, cooked with steam, mixed with sugar, and run through a pulper which forces the sauce through a screen with numerous small openings (0.30-0.75 in. in diameter). The pulper removes defects (peel, seeds, and carpel tissue) and produces the desired particle size or "grain." Canned applesauce is packed in hermetically sealed glass or metal containers and sterilized by heat.

A few companies in the United States and Canada presently manufacture applesauce without peeling, using the pulper and screen to eliminate the peel and seeds. Only green or yellow varieties are used. Red varieties are not suitable because of the instability of the red pigment.

Canned Sauce.—The standard applesauce pack is prepared from a blend of several varieties. This permits the use of dessert varieties, which contribute flavor, and cooking varieties to maintain texture or "grain." On the other hand, some single variety sauces have been successful.

In the middle 1950's, blends of applesauce with other fruits were introduced. Other specialty sauces have included "chunky" applesauce and a spiced applesauce. A gelled sauce has been marketed in Canada and the United States.

Frozen Sauce.—Applesauce preserved by freezing is prepared in the same manner as canned applesauce, but packed in frozen food containers and stored at -15°C.

Dehydrated Sauce.—Dehydrated applesauce may be prepared by several methods. The simplest pro-

cedure is to grind dehydrated low-moisture (2.5% H₂O) apple slices to a powder of the desired degree of fineness. The product may be reconstituted by adding hot water. The dried powder should be packaged in moisture tight containers to prevent caking.

A recent commercial process uses a modified double-drum drier to dry prepared applesauce. To overcome the stickiness of the dried film of sauce and to facilitate its removal from the hot drum, a jet of chilled air is directed at the product just prior to the doctor blade. The product is collected in a dry atmosphere and may be finish-dried to the desired moisture content.

Fresh Slices

Apple slices are used chiefly for remanufacture in bakery products, mostly pies. Large bakeries in the United States use the following types of apple slice product: frozen (including dehydrofrozen), 54%; fresh, 38%; and canned, 8%.

Fresh apple slices are used extensively by bakeries and large restaurants in the Eastern United States. By proper selection of varieties and use of cold storage, the season can be extended to 9-10 months. The apples are peeled, cored, trimmed, dipped in salt brine (with or without a trace of sulfite) and delivered on a daily basis.

Apple tissue contains oxidase enzymes and polyphenols which react to cause a brown discoloration when apple slices are exposed to air or when slices are frozen and thawed. Fresh slices may be protected against browning for periods up to 24 hr by dipping them in a 1-2% salt brine. Improved color and longer protection is obtained by adding 500 to 1500 ppm of sulfite to the brine. Apple slices to be frozen or dehydrated require a much more extensive treatment to prevent enzymatic browning.

Over-mature apples and some of the softer varieties tend to mush when cooked. This may be prevented by dipping or impregnating the slices with calcium salts which combine with the pectin and hemicellulose components of apple tissue to provide a firm, three-dimensional network. This treatment is used extensively to improve the texture and firmness of fresh, canned, or frozen slices.

Canned Slices

Canned apple slices are usually packed without syrup and are sufficiently processed by heat to assure preservation in hermetically sealed containers. The U.S. pack in recent years (1965-1967) has averaged nearly 4 million cases.

Canned apples are prepared from sound, firm, properly ripened fruit by peeling, coring, trimming, and slicing. Apple slices are inspected to remove

defects such as pieces of peel, calyx, and carpel tissue. This requires considerable hand labor and expense. A recent innovation, called a "hydro-sorter," uses an electronic eye to detect and eliminate defective apple pieces suspended in a stream of water.

One of the special problems encountered in canning apple slices is the presence of 5-25% of air in the tissues. If this air is not removed, it will cause mushing of the slices during cooking and extensive can corrosion during storage. Steam or hot water blanching will remove intercellular gases but often causes softening of the slices and leaching of flavor and nutrients.

There are several procedures using mechanical vacuum to remove the intercellular gases from apple slices. The fruit may be submerged in a liquid or syrup while being subjected to a vacuum of 24-28 in. (Hg). When the vacuum is released the liquid tends to flow into the spaces previously occupied by the gas.

A process used by many large manufacturers in the United States consists of releasing the vacuum with steam, so that the gas spaces are filled with condensate. This effectively preheats the slices prior to filling into the cans and very little further heat processing is required. Canned slices are heat-sterilized by heating to a center can temperature of 85°C.

Pie Filling.—Apple pie filling is made by canning a mixture of apple slices, sugar, starch thickener,

and citric acid. The U.S. pack in 1967 was 1.3 million cases valued at \$5.8 million.

Spiced Rings.—Apples are also canned as spiced rings. They are usually colored red or green.

Canned Baked Apples.—There are two types of canned baked apples. The more common type consists of whole apples, cored but not peeled, cooked by baking, and sufficiently heat-processed to be packed in hermetically sealed containers. Spice is added during baking and the apples are packed 2-3 to a container.

The other product is canned baked slices. The apples are peeled, cored, and quartered. The pieces are usually deaerated by vacuum to reduce mushing during baking. The baked slices are packed in glass, and given a further heat processing.

Frozen Slices

Between 3 and 4% of the U.S. apple crop is used in the manufacture of frozen slices. The U.S. pack in 1969 was over 100 million pounds. The principal problem in the preparation of frozen apple slices is the prevention of enzymatic browning during storage and especially after thawing. Sufficient treatment must be provided so that the sulfite penetrates to the center of the largest pieces. A simple rapid test for penetration of sulfite consists of treating a freshly cut section of fruit with a 1% solution of catechol. Any portions of fruit still containing oxidase activity will turn black.

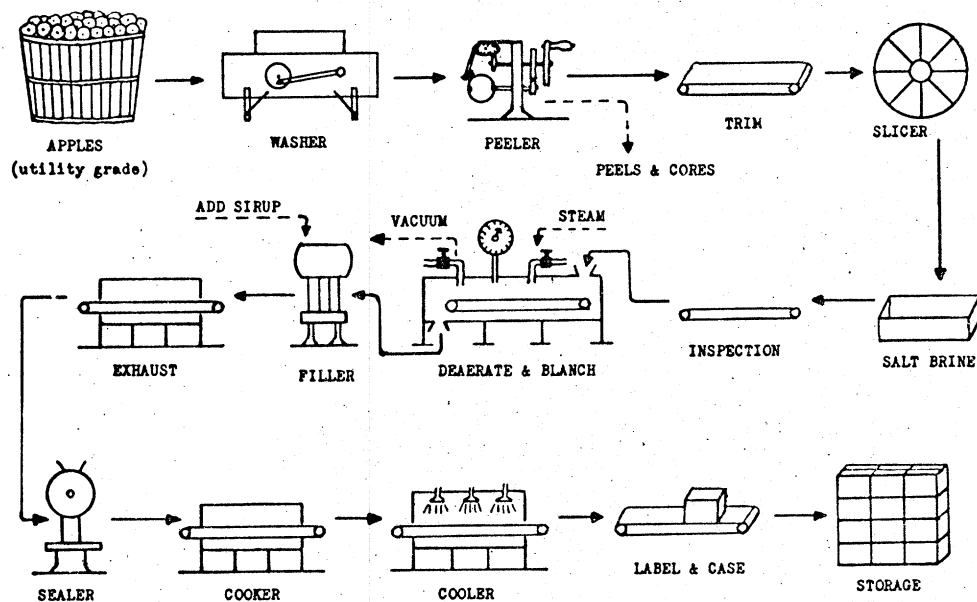


FIG. A-8. FLOW DIAGRAM OF PRODUCTION OF CANNED APPLE SLICES BY VACUUM AND STEAM PROCESS

The penetration of oxidase inhibitors is improved by removing the air from the apple slices by vacuum and then impregnating the slices with the desired solution. Some vacuum-impregnation procedures use sulfite solutions, others use sugar syrups, and others use mixtures of sugar syrup and ascorbic acid. It is claimed that sugar syrup impregnation exerts a slight firming action and improves the flavor.

Apple slices to be frozen are usually packed in metal containers holding 30 lb. The slices are packed with dry sugar or in a sugar syrup. The ratio of fruit to sugar is usually specified by the buyer. Common ratios are 5 plus 1 or 9 plus 1.

Dehydrated Apples

Nearly 4% of the U.S. apple crop is used in the production of dehydrated apple products. Dehydration involves the use of artificial heat to vaporize most of the water from apple pieces. The concentration of soluble solids (sugars, acids, etc.) is increased to the point that the fruit will resist microbial spoilage. Experience has shown that in the case of apples the moisture content must be 24% or lower. For some uses, an extremely low moisture content (2-3%) is desired.

The principal technical problem in the preparation of dehydrated apple products is the prevention of browning. This is generally accomplished by sulfiting. Dried products require more sulfite during preparation and storage than do frozen products.

The yield of dried apples will depend on the soluble solids of the original fruit and the size of apples. The average ratio of fresh to dried (24% moisture) is about 8:1. There are many types of dehydrators suitable for the primary drying stage but a vacuum dehydrator is required for the second stage.

Types of Dehydrators.—Kiln dryers and tunnel dryers are of historical interest. They were used prior to 1950 but have been replaced by more efficient dryers requiring less labor.

Belt dryers consist of long continuous belts of wire or perforated metal plates. Heated air may be drawn horizontally across the belt or directed vertically through the layer of fruit. The dryers are usually divided into stages, using hotter air in the initial stage. These dryers are efficient, easy to regulate, and widely used commercially.

The belt trough dryer is a new, efficient type of dryer operating at relatively high temperatures. The belt passes through a "trough." This stirs or rotates the bed of fruit pieces so that they are exposed to heat for only a short portion of the drying cycle.

Vacuum dryers are used to produce dehydrated apples with 3.5% or less moisture. Apple slices,

previously dried to about 24% moisture, are chopped or diced in order to increase the surface area. The fruit is dried on trays in a vacuum chamber by a batch process. The product is hygroscopic and must be packaged so as to exclude moisture.

Explosion puffing is a new method of preparing dehydrated apple pieces with a porous structure. Dried apple pieces of (20-30% moisture) are placed in a closed vessel or "gun," heated to 20-30 lb pressure, and the pressure released suddenly through a quick-opening lid. The flashing of water vapor causes the apple pieces to expand to their original volume. This creates a porous structure that permits a more rapid final dehydration. Because of its porous structure it also rehydrates rapidly. Explosion-puffed apples may be ground to produce an "instant" dried apple sauce.

Dehydrated Products.—The principal dehydrated apple products are dried apples and dehydrated (low-moisture) apples. USDA grades are based on moisture content and quality as judged by flavor, odor, color, texture, uniformity of size, and freedom from defects.

Dried apples consist of slices, rings, or pieces that have been sulfured sufficiently to retain a characteristic color, and dried to a moisture content of not more than 24%.

Dehydrated (low-moisture) apples are similar but must have not more than 2.5% moisture for Grade A, and not more than 3.5% moisture for Grade B.

"Apple Chops" consist of whole apples which are sliced and dried, frequently without treatment to prevent darkening. Small fruit, unsuitable for use in products requiring peeling, may be used. Apple chops are used in preparing apple butter and other products where color and blemishes such as bruises are not a factor in quality.

Dried applesauce may be prepared by grinding "low-moisture" apples to the desired particle size or by drum drying a prepared apple sauce.

Dehydrocanned apples is a potential new product not yet in commercial production. Slices are dried to a 50% weight reduction and then canned. The savings in container, storage, and shipping costs more than offset the cost of dehydration.

Dehydrofrozen slices are prepared by a combination of two processes: drying and freezing. Apple slices are sulfited, dried to a 50% weight reduction, and then frozen without added sugar. The product may be packed in cardboard cartons, which are less expensive than the usual metal containers used for single-strength frozen slices. The frozen pieces are free-flowing, easy to handle, and rehydrate rapidly. The product has been in commercial production in the United States since 1956. It is estimated that the 1965 production was more than 20 million pounds on a rehydrated weight basis.

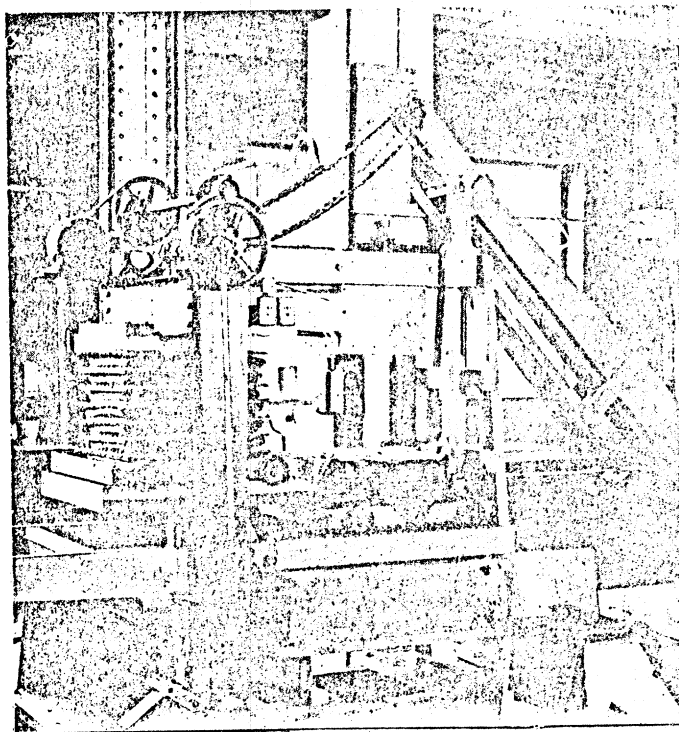
Apple Juice Products

On a worldwide basis, apple juice products, fresh and fermented, exceed all other apple products combined. Only in the United States do sauce and slice products exceed juices in volume of production. The apple juice pack in the United States, for the period 1965-1969 averaged about 35 million gallons per year. There are no reliable statistics on the volume of fresh cider sold per year but estimates place the volume at 20-25 million gallons.

There is considerable confusion over the terms used for apple juice products. In Europe, "cider" refers to fermented apple juice. The unfermented product is called "apple juice" or "apple must." In this section, for the sake of clarity, we will use the nomenclature commonly used in the United States. "Apple juice" refers to the product preserved by heat and packed in hermetically sealed containers. The unfermented juice from apples is called "cider" or "fresh cider." The fermented product is called "hard cider." There is one notable exception to the above nomenclature: some manufacturers sell pasteurized apple juice in the fall in 1 gal. or 1/2 gal. glass jugs labelled "cider." This is to take advantage of the seasonal sales appeal of "cider."

Fresh Cider.—Fresh cider is usually prepared in small-scale operations using less expensive equipment than required for the manufacture of pasteurized apple juice. In both operations the manufacturer is limited to those apple varieties available, usually the small sizes which cannot be peeled economically, second grade or surplus fruit from the fresh market, and some windfalls or drops. Blending of varieties is a common practice and provides a more uniform product throughout the season as well as permitting the use of some varieties that are unsuitable when used alone.

The apples are washed, inspected, and trimmed to remove any decay which would affect the flavor. Small cider mills have a grinder or grater mounted above the press. The ground pulp falls into a frame lined with a press cloth. A 2-3 in. layer of apple pulp is wrapped in the press cloth to form a "cheese." Successive layers of "cheeses" are separated by thin slatted wooden racks and built one on top of the other. The juice is expressed by a hydraulic press which exerts a pressure of about 75 lb psi. A pressing cycle requires 20-30 min and the yield is about 160-170 gal. of juice per ton of apples. The juice, or fresh cider, is usually allowed to settle overnight to remove the coarser suspended material.



Courtesy of M. A. Audsley, USDA

FIG. A-9. RACK AND FRAME APPLE JUICE PRESS

Fresh cider contains yeasts, molds, and bacteria which cause spoilage within 1-2 days at room temperature. There are several methods used to delay or prevent fermentation. Refrigeration at 0°-10°C retards the growth of yeasts and molds, and especially bacteria, and extends storage life to 1-2 weeks. Some fresh cider is stored in a frozen condition and thawed for use later in the year.

Until recently most apple cider was preserved by the addition of benzoate of soda. State and federal laws permit the use of amounts up to 0.1%. This will prevent spoilage for about one week at room temperature and several weeks at lower temperatures. Benzoate imparts a noticeably sharp, disagreeable after-taste to apple cider. In the past 10 yr, potassium sorbate has largely replaced benzoate as a chemical preservative for apple cider. Sorbate has little, if any, taste and is nearly as effective as benzoate. Both chemicals are very effective preservatives when used in combination with storage temperatures below 10°C.

Ultraviolet (UV) irradiation is a new procedure for preserving apple cider without affecting the flavor. A few seconds exposure to UV destroys 90-99% of the microorganisms present. Regrowth occurs at a normal rate unless a small quantity of chemical preservative is added, or the cider is stored at 10°C or below.

Fresh cider is gaining rapidly in popularity in the United States. Although most cider is sold at

roadside markets, there is an increasing quantity distributed through dairies and supermarkets.

Pasteurized Apple Juice.—Large volumes of pasteurized apple juice are sold in the United States and Canada and in most European countries. Apple juice is manufactured in large installations and somewhat more care is taken to ensure uniform quality and maximum economy than in the manufacture of cider. The USDA has established Grades for Canned Apple Juice. Grade A (Fancy) apple juice shall have a soluble solids content not less than 11.5° Brix and an acid content (calculated as malic) between 0.25 and 0.70%. The requirements for Grade B are 10.5° Brix and between 0.20 and 0.80% acid. The flavor and tartness of apple juice are related to the Brix:acid ratio.

Apple juice should be prepared from sound, properly ripened fruit. The apples are washed, inspected, and trimmed prior to grinding. Hammer mills with dull or serrated blades give maximum disintegration of the tissues and high yields of juice. Until recently, the rack and frame press was commonly used for the manufacture of apple juice. Today it has been largely replaced by semi-automatic presses or continuous presses, with a saving in labor and improved sanitation.

The Willmes press is widely used in the United States and Canada. It consists of a large horizontal cylinder with heavy perforated walls, which may be lined with press cloths. In the center of the cylinder is a heavy rubber innertube. Ground apple pulp is

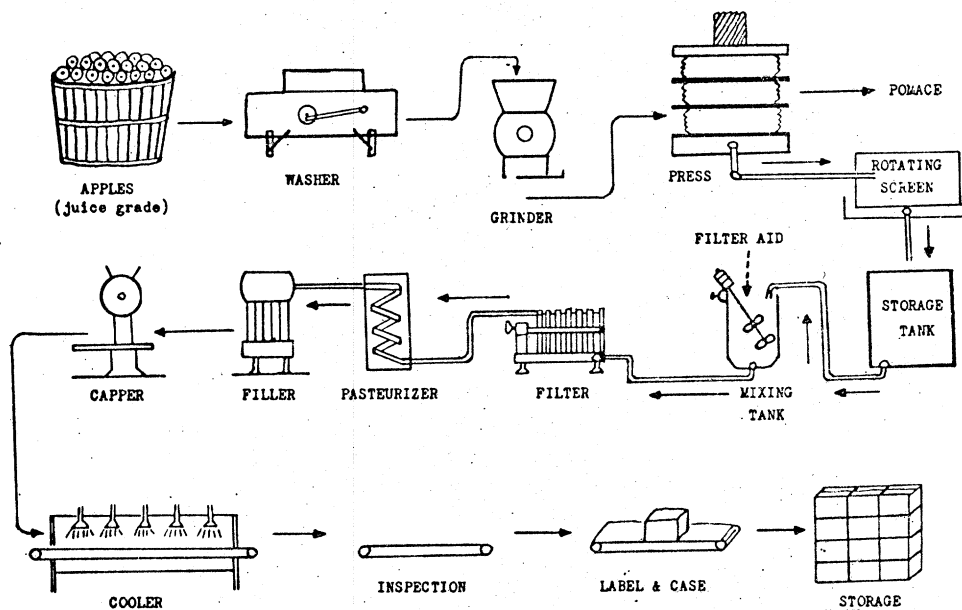


FIG. A-10. FLOW DIAGRAM FOR PRODUCTION OF PASTEURIZED APPLE JUICE

loaded into the cylinder, the doors are closed and the innertube is inflated using pressures up to 80 lb psi. Although it is a batch process, it requires a minimum of labor and produces excellent yields of juice.

There are several types of continuous presses. One type uses a mechanical screw to force the apple pulp against a pressure plate. Another type uses a long, continuous cloth belt which is folded and pressed between a series of converging rolls. A third type uses a large basket centrifuge followed by a vertical screw press.

Freshly pressed juice contains a large amount of colloidal material and coarse suspended solids. The suspended solids may be removed by filtration or centrifugation to yield a "cloudy" apple juice. Approximately 25% of the apple juice produced in the United States is "cloudy" and the rest is "clarified."

Historically, the earliest processes for clarifying apple juice used heat clarification, gelatin-tannin precipitation, or treatment with bentonite. These procedures were slow, inefficient, and unreliable. Today most apple juice is clarified by using pectolytic enzymes. The juice is then filtered and sterilized by heating to approximately 85°C for 15-30 sec. The hot juice is filled into either metal or glass containers, sealed, cooled, and labelled.

Other Juices and Blends.—Natural apple juice is prepared by adding sufficient ascorbic acid (vitamin C) to the apples at the time of grinding to prevent oxidation. The juice is strained, not filtered, and retains the flavor of fresh apples even after heat sterilization. This juice is very popular in Canada but has not sold well in the United States.

Crushed-apple juice is a pulpy juice containing 3-10% of finely ground, suspended apple pulp. Special grinding mills pulverize the apple and force the juice through a screen with 1600-3600 holes per square inch. The juice is then deaerated, homogenized, and heat sterilized.

Blends of apple juice with other fruit juices such as cherry, grape, cranberry, and raspberry have been marketed in small to moderate volumes. The proportion of apple juice in the blend is usually 60-85%. Apple juice "drinks" are similar to blends but contain such added ingredients as sugar, acid, coloring, and water. There are no standards at present for such products.

Syrups, Concentrates, and Essence

The manufacture of apple sauce and slice products results in large quantities of peels and cores—approximately 30% of the fruit. It is estimated that the juice from grinding and pressing this volume of material would be equivalent to 40 million gallons per year in the United States. This juice is not suitable for sale as apple cider or canned

juice but is used in the manufacture of vinegar and various concentrates and syrups. Concentrates for beverage use are prepared from juice grade whole apples.

Boiled cider was one of the first apple products prepared on the farm. Small quantities are still made for use in home-made apple butter. It is made by boiling cider at atmospheric pressure until it reaches a syrupy consistency. It has a dark brown color and a caramelized flavor.

Apple concentrate: Prior to concentration, the apple juice is depectinized by pectolytic enzymes. If this is not done, gelation would result. Water is removed by vacuum evaporators at a temperature below 60°C to prevent heat damage to the product. Apple concentrate (68°-72° Brix) is an item of international trade. It is used in the manufacture of jellies and apple butter.

Apple essence: In the manufacture of apple concentrate the aroma, characteristic of fresh apple juice, is volatilized during the early stages of evaporation. A commercial process, developed in 1944, retains the volatile constituents and concentrates them by fractional distillation. The usual product is a 150-fold "essence." It is used to fortify the flavor of apple jellies and "full-flavored" apple juice concentrates.

Apple syrup for table use is commonly prepared by concentrating apple juice to 20°-30° Brix and then adding sugar to the desired concentration, usually 65° Brix.

Full-flavored concentrates for beverage use are prepared by concentrating apple juice and adding back apple essence. They are marketed either as a 4:1 frozen concentrate or a 7:1 heat-sterilized, canned product.

Semiconcentrates: In Switzerland and other European countries in recent years a process has been developed for the bulk storage of 4-fold apple juice concentrate. The product is stored at 0°C in large metal tanks under carbon dioxide. It is used for the remanufacture of single-strength apple juice.

Apple juice powder is an experimental product which reconstitutes with water to give a full-flavored apple juice. A 60°-80° Brix concentrate is dehydrated on a thin-film cone to a moisture content of 1-4%. The hot molten mass is mixed with a highly concentrated apple essence (700- to 1000-fold), chilled on cooling rolls, ground, and packaged with a desiccant.

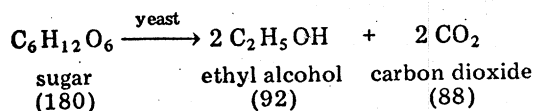
Fermented Juice Products

In Europe, large quantities of apples are used in the production of fermented beverages. Products such as hard cider, wine, and brandy are common throughout Europe but are relatively unimportant

in the United States. On the other hand, large quantities of cider vinegar are produced in the United States and Canada, yet this product is scarcely known in Europe.

Terminology: The confusion over the meaning of the term "cider" was mentioned in the section on apple juice products. Common usage in the United States and Canada refers to cider as the fresh, unfermented juice from apples. The product of normal alcoholic fermentation, containing between 0.5 and 8.0% alcohol by volume, is called "hard cider" or "fermented cider."

Fermented Cider.—Fermented apple juice products are prepared from apples that are washed, sorted, ground, and pressed in the same manner as outlined for apple juice products. Fermentation may be accomplished by naturally occurring yeasts or by adding a desirable strain of yeast. During fermentation, the yeast converts sugars to alcohol and carbon dioxide.



Theoretically, 180 gm of a hexose sugar would be converted to 92 gm of alcohol and 88 gm of CO₂. These yields are never achieved in practice because the yeast utilizes some of the sugar and alcohol for growth and energy.

Dry (hard) cider: Fully fermented apple juice with little or no residual sugar is called a "dry" or "hard" cider. Sugar may be added before fermentation to raise the alcohol content of the final product to 6-7%. The product may be heat-sterilized by heating to 65°C.

Sparkling cider: This product is produced by allowing fermentation to proceed to about 3.5% alcohol. An effervescence is produced by allowing a portion of the carbon dioxide to be retained in the finished product.

Carbonated cider: This term is applied to any fermented apple cider that has been charged with commercial carbon dioxide to produce effervescence.

Champagne type cider: Champagne type cider is produced in a manner similar to that employed in preparing champagne. Effervescence is produced in the final product by a secondary fermentation of the dry cider after it is bottled.

Apple Wine.—Apple wine is the most common fermented apple beverage in the United States and Canada. The annual production in the United States for 1970 was about 770,000 gal. Apple wine is less common in Europe where the principal alcoholic beverages from apples are hard cider and brandy.

Apple wine is a fermented product containing 8% or more of alcohol. Natural apple juice when fully fermented usually contains less than 7% alcohol, since about 2% sugar is required in the juice for each 1% of alcohol produced. Therefore, in the manufacture of apple wine, it is necessary to add more sugar. The highest alcohol content reached by natural fermentation is approximately 13%. Wines of higher alcohol content require fortification.

Apple wine is aged in tanks or casks, preferably of oak, for 2-3 months. This eliminates the yeasty taste and produces a mellow flavor and aroma. It is then filtered and pasteurized at 65°C.

For purposes of taxation, the United States Government recognizes 3 classes of wines based on their alcohol content: (1) 8-14% alcohol, by volume, produced by natural fermentation in the presence of adequate sugar; (2) 14-21% alcohol, fortified by adding apple brandy; and (3) 21-24% alcohol, also by fortification. Apple wines are further classified on the basis of their sugar content as sweet, semisweet, or dry (low in sugar). Effervescent apple wines, in which the carbon dioxide charge is produced either by natural fermentation or by artificial carbonation, constitute additional types which are subject to special tax rates.

Apple Brandy.—The term "apple brandy" is derived from "burnt wine." Actually, it is a distillation product of fermented apple juice or hard cider. Apple brandy is also known in the United States as "Applejack" and in Europe as "Calvados."

France, the principal apple brandy producing country in Europe, produced 7 million gallons (100% alcohol equivalent) annually in the late 1930s, but in recent years the production has been only 2 million gallons per year. The United States produced nearly 1.4 million gallons of apple brandy in 1945 but in 1970 the production was only 430,000 gallons.

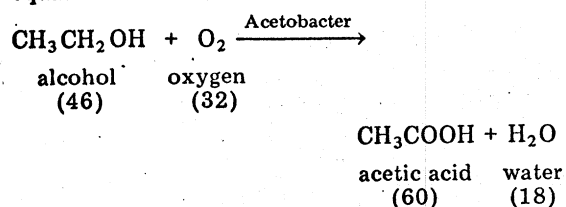
Beverage brandies contain 55-65% alcohol. They are preferably aged in oak casks until suitably mellowed. High proof brandy, rectified to as high as 95% alcohol (190° proof), is commonly used to fortify wines.

Industrial alcohol: Sporadic attempts have been made to produce alcohol from apples for industrial purposes. On a commercial basis about 80% of the total sugar equivalent of apples is converted to alcohol. Thus, a ton of apples (11% sugar) would yield about 12.8 gal. of 100% alcohol. The cost of raw materials and cost of production would not make this an economical source of industrial alcohol.

Cider Vinegar.—Vinegar (sour wine) is a self-preserving product resulting from the oxidation of alcohol to acetic acid by *Acetobacter* fermentation.

Approximately 30 million gallons of cider vinegar is manufactured in the United States per year. Cider vinegar is widely used in North America as a flavoring and preserving agent. In Europe, vinegar is prepared from a wide variety of materials, including apples, other fruits, and cereal grains.

The conversion of alcohol to acetic acid by *Acetobacter* may be represented by the following equation:



Theoretically, 46 gm of alcohol yields 60 gm of acetic acid. Large quantities of oxygen are required and provision must be made to remove the heat produced by fermentation, which is equivalent to 2550 gm calories per gram (4600 BTUs per lb) of alcohol.

History of vinegar production: vinegar-making is a very old art. The oldest method consisted of exposing fermented fruit juice in open vats to the action of airborne vinegar bacteria. The method is called the "Orleans process," after Orleans, France. A slime of bacteria, called "mother of vinegar," converts the alcohol to acetic acid. The process is slow and the efficiency is around 50%.

In 1824, a German chemist named Schutzenbach developed a process of trickling vinegar stock over wood shavings supported in an upright tank or generator. The increased surface speeded up acetification and gave conversion efficiencies of 60-80%. This method with some improvements was used until the late 1940s.

Today, most vinegar is manufactured by submerged culture methods, similar to procedures developed during World War II for the production of antibiotics. The Frings Acetator was developed in Germany in 1955. It consists of a 2000 gal. stainless steel tank equipped with a rotor to pump finely dispersed air through the liquid. Cooling coils maintain the temperature at 30°C. The efficiency of this method is 95-98%.

Preparation of vinegar: Cider vinegar is usually prepared from cull and surplus apples and from the peels and cores of apples used for sauce and slice products. The pressings, containing approximately 11% sugars, are stored several months in large tanks to allow the sugar to ferment to alcohol. The fermented mash, or vinegar stock, is placed in the generator tank together with a culture of *Acetobacter* from the previous batch. The operation requires about 24 hr per batch. This system

can be operated on a continuous automatic basis by the careful adjustment of incoming alcoholic mash and outflow of vinegar. The fermentation is allowed to proceed until the alcohol content falls to 0.2-0.3%.

After acetification, vinegar is aged to develop flavor and to assist in clarification. The vinegar is filtered in the same manner as used for apple juice. Some cider vinegar is delivered in bulk without pasteurization, but most of it is pasteurized at 65°C and bottled.

Cider vinegar usually contains 4-5% acetic acid. The concentration is often expressed as grains, in which case 10 grains is equivalent to 1%. Thus a 40-grain vinegar would contain 4% acetic acid.

Apple Jelly, Butter, and Other Confections

The home preparation of fruit jellies, jams, and butters was the forerunner of the giant modern preserving industry in the United States which produces over 800 million pounds of these items per year. Although there are no accurate data on the quantities of items prepared from apples, it is estimated that the 1967 production of apple and apple-base jellies was about 100 million pounds and apple butter was about 30 million pounds.

Apple Jelly.—Three substances are essential to the preparation of a fruit jelly: pectin, acid, and sugar. Sufficient pectin is added to give a jelly of the desired texture. Acid is necessary to aid in the formation of a hydrogen-bonded, three-dimensional network of sugar and pectin. The usual sugar concentration for jellies and preserves is 65% or higher. This concentration is necessary for gel formation and is sufficient to make the product self-preserving under normal conditions. The FDA has developed Standards of Identity for various food products including fruit jellies, jams, preserves, and butters.

Jellies differ from jams and preserves in that they are clear, free of insoluble solids, and have a definite gel structure rather than a semisolid consistency. By definition, apple jelly contains not less than 45 parts by weight of apple juice (or equivalent amount of concentrate) to each 55 parts of sugar. Apple-base jellies are made from a mixture of apple and other fruit juices. They usually contain 80% apple and 20% of the minor, more expensive fruit.

In commercial practice apple jelly is prepared from concentrate rather than single-strength apple juice. Calculated quantities of concentrate, sugar, pectin, and citric acid are heated in a vacuum pan to remove sufficient water to achieve a soluble solids content of at least 65%. The jelly is hot filled at 85°C into glasses, cooled, allowed to set, and then packaged.

Apple Butter.—Apple butter is a smooth, semi-solid mixture of apple pulp and sugar. Apple juice (or concentrate) may be added to provide more apple flavor. The soluble solids requirement is only 43%. Apple butter is usually prepared by cooking 5 parts apple pulp and 2 parts dry sugar, or 2 parts apple pulp and 1 part apple juice. The mixture is cooked several hours to develop a brown color and a caramelized flavor.

Other Confections.—Candied apples are prepared by impregnating pieces of apple with sugar syrup and then drying and glazing to overcome stickiness.

Apple candies are specialty confections and their method of preparation depends on the ingenuity of the individual candy maker.

Pomace and Pectin

Apple Pomace.—Apple pomace consists of the press cake resulting from pressing apples for juice. The principal uses for apple pomace are (a) as feed for livestock, and (b) for manufacture of pectin.

Fresh apple pomace has about 75% of the feeding value of corn (maize) silage when fed to dairy cattle. Preservation by fermentation to produce ensilage is a common procedure when the pomace is to be used as a stock feed.

Apple pomace is often dried and mixed with other feeds. In recent years dried apple pomace has been little used for stock feed in the United States because of the restrictions on spray residues.

Apple Pectin.—Commercial pectin manufacture began in Germany and Italy around 1908, with dried apple pomace as a source of material. Pectin production in the United States reached a peak during World War II when large quantities were exported to Europe. During 1943–1946, over 6 million pounds of pectin were produced annually in the United States. About 30% of this quantity was derived from apples. In 1967 only 10% of the U.S. production was from apple and the remainder was from citrus.

Pectin is extracted from dried apple pomace by mild acid hydrolysis. A mixture of pomace, water, and sufficient acid to give a pH of 3.0 is heated to 90°C for 1 hr. The extract is removed by pressing, then clarified and filtered. Pectin is sold either as a liquid concentrate or as a dried powder.

Pectin is marketed on the basis of "grade," which is defined as the number of units (grams or pounds) of sugar that can be made into a 65% sugar jelly of standard firmness by one unit (grams or pounds) of pectin. Dried apple pectin may vary from 150 to 180 grade but is usually standardized at 100 grade by diluting with sugar.

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Cross-reference: *Dried Fruit; Pectin; Vinegar.*

APRICOTS AND APRICOT PROCESSING

Three species of plum genus *Prunus* are known as apricots. They are: *P. armeniaca*, the common apricot, *P. mume*, the Japanese apricot, and *P. dasycarpa*, the black apricot. The apricot-plum, *P. simonii*, is more closely allied to the plums and is usually classified as a plum.

The apricot is an intermediate between the peach and the plum. The three fruits may be readily intergrafted, and the apricot and plum have been hybridized, the hybrid being called the plumcot, while a supposed hybrid between the peach and apricot is called the peach-apricot.

The common apricot grows spontaneously over a wide area in western and central Asia and as far eastward as Peking, China. Alexander the Great is said to have brought the apricot from Asia to Greece. From there, it was carried to Italy, being first mentioned as a Roman fruit by Pliny in the time of Christ. From Italy, its culture spread slowly northward in Europe, reaching England about the middle of the 14th Century. There seems to be no mention of the apricot in North America until 1720, when it was said to be growing in the mission orchards of California. However, commercial plantations were not started in California until the latter half of the 19th Century. The Blenheim apricot is grown extensively in counties near San Francisco Bay. It is the most sought after for canning purposes. The Tilton, also an important variety for canning, although not as desirable as the Blenheim, is grown in the hot interior valleys of California.